SOURCE TERM BALANCE FOR FINITE DEPTH WIND WAVES

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LONG-TERM GOAL

The long-term goal is to obtain closure of the energy balance equation for wind wave evolution in finite depth water by means of direct measurement of the main source terms. These source terms represent the basic physical processes required to develop reliable finite depth wave prediction models.

SCIENTIFIC OBJECTIVES

The objectives are to establish a description of the basic sources/sinks of energy responsible for shallow water wind wave evolution, namely dissipation due to both wave breaking and bottom friction, and wind input. Spectral distribution of "white-capping" dissipation has not previously been obtained either experimentally or theoretically, and currently speculative approaches are used to represent this term in wave models. The natural phenomena determining this term are random, nonlinear and related to extreme wave conditions and hence are difficult to evaluate in the field. The other two terms have been the subjects of intensive research during the last three decades, although detailed field observations are rare. There is a qualitative understanding of their behaviour, however, no established quantitative description is available.

APPROACH

An experimental site at Lake George near Canberra, Australia is being established. The Lake is a shallow water basin and closely approximates the idealised case of finite depth fetch limited growth. The experimental site includes an observational platform with a shelter to accommodate electronics and equipment as well as researchers during observations. An anemometer mast has been erected 10 m from

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the platform to avoid disturbance of air flow with a measurement bridge between the platform and the mast. This bridge will be used for the majority of the wave measurements. Two shelters have been erected on the shore to provide basic storage and accommodation for researchers during their stay at the site. The location has vehicular access, a simple offshore bathymetry and water of approximately 1.5 m depth within 50 m of the shoreline. The platform, located approximately 50 m offshore is shore-connected with an elevated walkway and is thus accessible in any weather conditions. Computer facilities allow for preliminary data analysis to be performed on the spot though the main data processing will be done in the Australian Defence Force Academy (ADFA). The site is located approximately one hours drive from ADFA and measurements are carried out whenever meteorological forecasts are appropriate.

To measure "white-capping" dissipation, four different but integrated instrument systems are being employed. Direct in situ estimates of energy lost by breaking waves are performed by means of an array of capacitance wave probes which allows also for measurement of directional wave spectra. It is also planned to deploy two additional wave probes, in front of and behind the array, and provide an observer with the possibility of electronic marking of visually observed breakers. Facilities for quick in situ calibrations of the wave probes are available. An Acoustic Doppler Velocimeter (ADV) is employed for measurement of dissipation rate through the water column in the vicinity of the array. An underwater hydrophone, the output from which is related to both the strength and dimension of breakers, is located on the bottom beneath the array. Video recording of the surface spot around the array is used to identify breaking events and to supply information on the spatial dimensions of white-capping. The logging of all systems is synchronised.

Simultaneously, measurements in the atmospheric boundary layer are also being conducted. The anemometer mast has six cup anemometers logarithmically spaced from 0.5 m to 10 m and two wind direction vanes. In addition to these wind profile measurements, a sonic anemometer is also deployed on the mast. A wave following pressure system, presently being developed by M. Donelan will be deployed during the 1998 winter (August-September) to explore wave-induced stresses and pressure fluctuations in the wind.

It was initially proposed to measure the bottom shear stress with a bottom mounted shear plate. Initial tests, however, indicate that the mud bottom of the lake will not be suitable for this instrument (a laboratory version is operational). Hence, it is now proposed to collaborate with T. Stanton to measure the bottom friction term with a high resolution Doppler profiler.

Full analysis of the data will include a modelling phase, in which the EXACT-NL model of Hasselmann will be used to compare the predicted evolution of the wave spectrum with the measured source terms with the extensive observations of fetch limited evolution which have been made in Lake George over a period of five years.

WORK COMPLETED

The experimental site at Lake George has been established to a major extent and regular measurements have commenced. The research platform has been constructed, power supplied and most of the computers, electronics and instrumentation installed. The elevated 50 m long walkway connects the platform to the shore where the two accommodation and storage shelters have also been built. The anemometer mast has been deployed with a complete boundary layer array. The wave gauge array, ADV vertical traversing system, video monitoring and hydrophone are all operational. In addition, a software

package which logs all instruments simultaneously and provides real time monitoring has been developed.

Measurements were commenced in early September and include: wave array, ADV, hydrophone, video camera, mast with 6 cup anemometers and 2 wind direction meters, sonic anemometer, air temperature and humidity, all of which are recorded electronically, together with manually measuring water temperature and depth. The depth of the lake varies seasonally and as a result of wind setup.

These initial measurement have confirmed successful operation of all instruments, together with the integrated logging system.

RESULTS

Construction of the research facility began in April, 1997 with the first measurements being conducted in September, 1997. The measurements conducted to date have been mainly aimed at confirming successful operation of the integrated instrumentation systems. The photographs below show the experimental platform with the instrumentation deployed. The photo on the left shows the platform viewed from the shore-connected walkway. The anemometer mast with its boundary layer array is visible to the right of the platform. The photo on the right shows the measurement bridge which connects the platform to the anemometer mast. The directional array can be seen deployed below the bridge. The ADV and hydrophone are deployed below the array.

Initial tests indicate that all systems are performing well. Figures 1, 2 and 3 shows measurements of the atmospheric boundary layer, surface wave spectrum and sub-surface current field, respectively. The atmospheric boundary layer measurements clearly show a logarithmic structure with turbulent velocities which decay as $f^{-5/3}$. The wave spectra show a high frequency decay proportional to f^{-4} with a directional spread about the wind direction (westerly in this case). The current meter measurements show a decrease in the standard deviation of the velocity fluctuations with distance below the water surface and spectra which decay proportional to $f^{-5/3}$. The data shown here were recorded under westerly winds with $U_{10}\approx 10$ m/s.

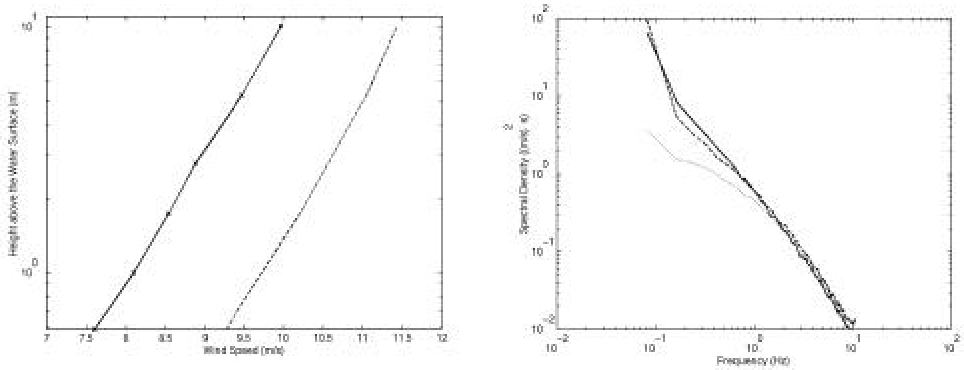

Fig. 1. Measurements in the atmospheric boundary layer. Left: Boundary layer profile, average wind (solid line) and gust (dashed line) . Right: Wind velocity spectra; north-south, east-west and vertical components correspond to solid, dashed and dotted lines respectively.

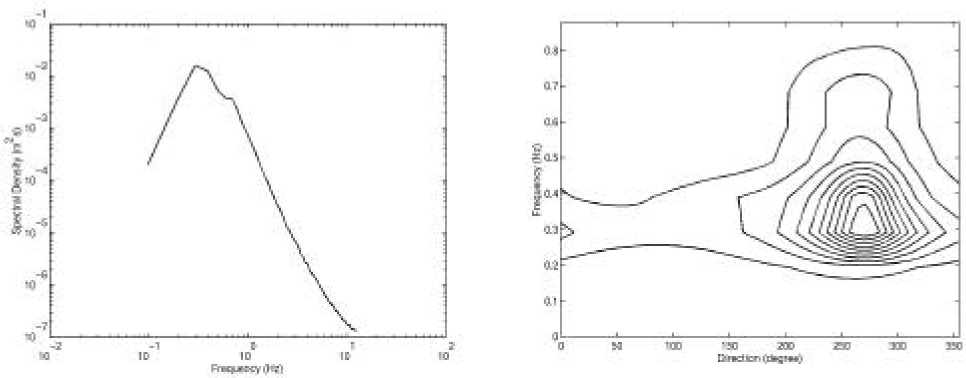

Fig.2. Surface wave spectra. Left: One dimensional frequency spectrum. Right: Contour plot of directional wave spectrum .

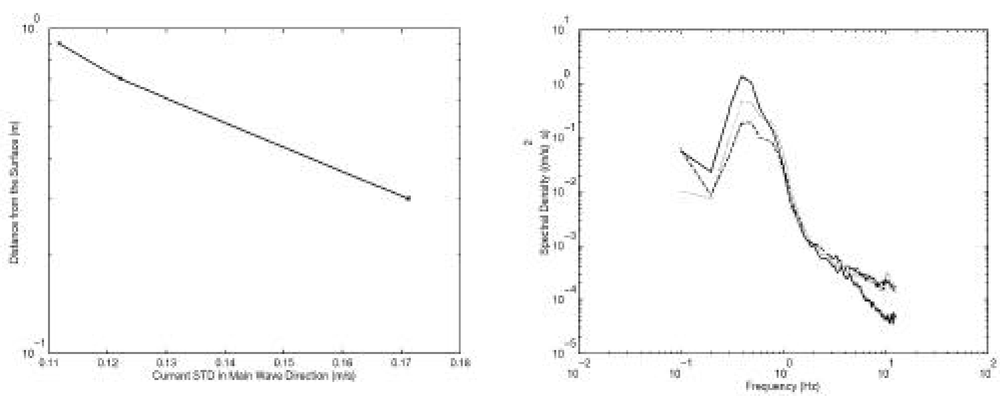

Fig.3. Measurements in the subsurface boundary layer. Left: Profile of the standard deviation (std) of current in the main wave direction taken at three elevations. Right: Current velocity spectra; main wave direction correspond (solid line), perpendicular wave direction (dashed line), and vertical direction to (dotted line).

IMPACT/APPLICATION

Results of the field research and parameterization of the source terms will have potential impact in a number of areas.

1). Wind Wave Dynamics. Direct, simultaneous, in situ field measurements of the major source terms together with detailed knowledge of the spectral evolution have not previously been attempted. The results have the potential to provide considerable insight to present understanding of wind wave evolution in finite depth water.

2). Wave Modelling. Source terms presently used in finite depth wave prediction models are largely extrapolated from deep water experience. Direct measurement of the source terms in such situations will provide a more appropriate representation for the physical processes in such models. As a result, an enhanced ability to predict nearshore wave conditions should result.

TRANSITIONS

Two groups have expressed interests in using the Lake George facility and one group is intended to use results of the experiment for verification of their theoretical models.

Tim Stanton from the Naval Postgraduate School, Monterey, USA will collaborate in the program by providing their bottom boundary layer profiler and bistatic system for the measurement of the bottom boundary layer.

Murray Smith from the National Institute of Water & Atmospheric Research, Wellington, New Zealand is intended to use their microwave backscatter radar system in collaborative investigations of the dissipation due to wave breaking.

Vladimir Makin from the Royal Dutch Meteorological Institute, De Bilt, The Netherlands plans to provide theoretical interpretation using data of observed distributions of mean and wave-induced stresses by means of his wind-wave coupling model.

RELATED PROJECTS

This project will be coordinated with the other DRI experiments planned for Duck, North Carolina. As the experimental site provides good control over the environmental parameters, it is hoped the experiment may well fill some of the gaps in the larger scale, open ocean DRI measurements. Measurements will be conducted throughout late 1997 and early 1998. An intensive measurement program will be conducted with an expanded instrumentation system (surface pressure and bottom boundary layer) in August/September 1998. This will be in advance of the Duck program and hence should provide valuable planning data for these experiments.

REFERENCES

To date, there are no publications for this project.